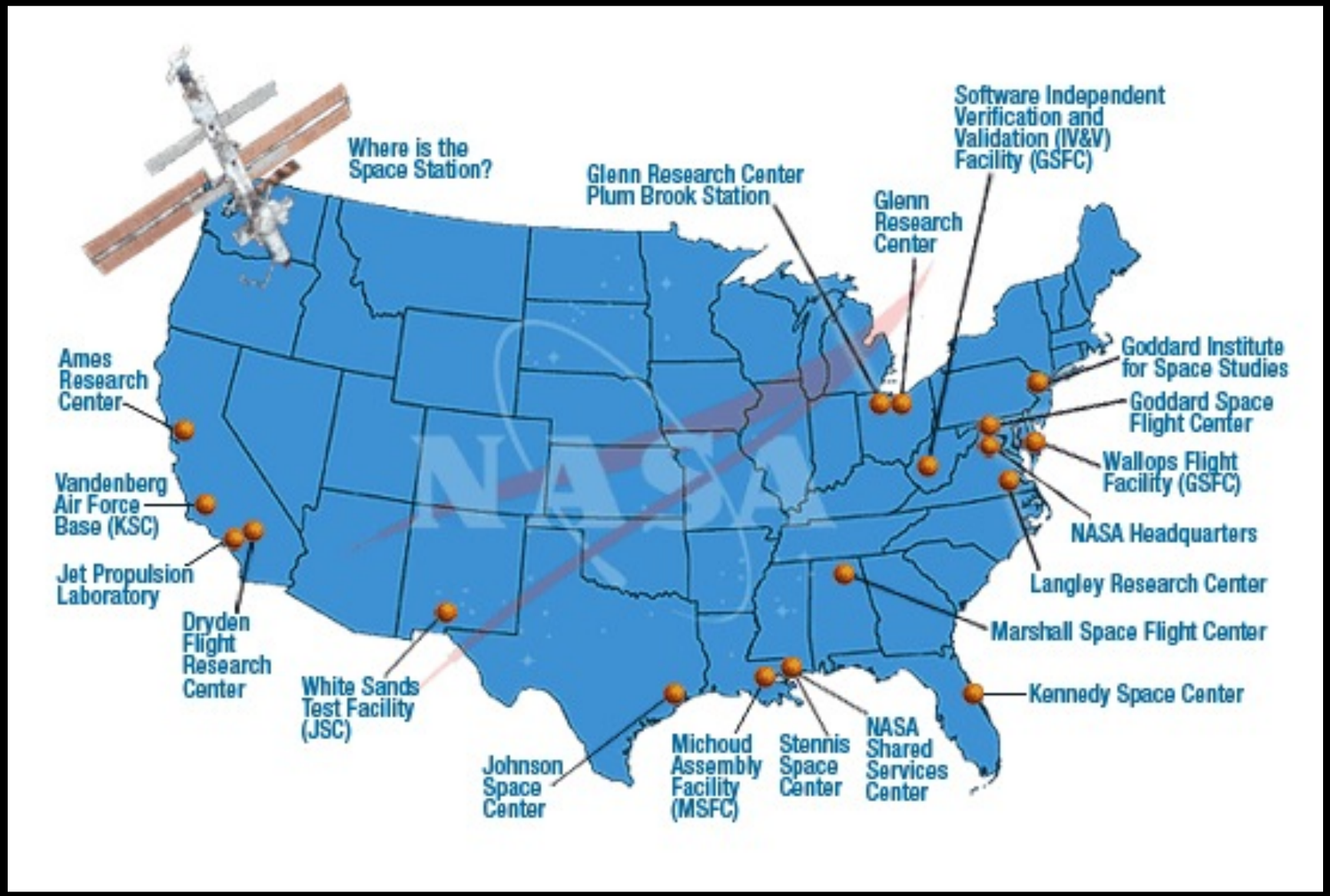
Open Source Mission Control for Chrome

Jay Trimble
NASA Ames Research Center

NASA


Where is the Space Station?
Glenn Research Center Plum Brook Station
Glenn Research Center
Software Independent Verification and Validation (IV&V) Facility (GSFC)
Goddard Institute for Space Studies
Goddard Space Flight Center
Wallops Flight Facility (GSFC)
NASA Headquarters
Langley Research Center
Marshall Space Flight Center
Kennedy Space Center
NASA Shared Services Center
Stennis Space Center
Michoud Assembly Facility (MSFC)
Johnson Space Center
White Sands Test Facility (JSC)
Dryden Flight Research Center
Jet Propulsion Laboratory
Vandenberg Air Force Base (KSC)
Ames Research Center

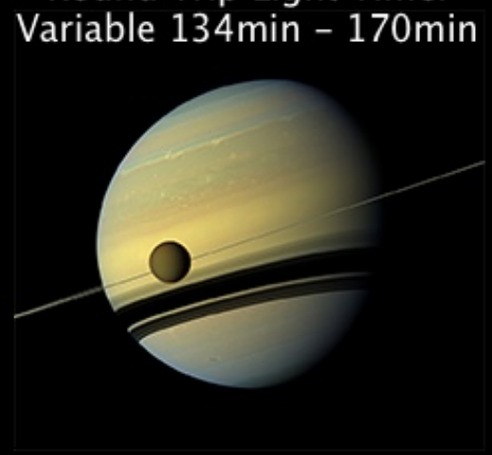
Missions

- Extend our senses with robots and instruments
- Extend our presence with people
- Mission Experience
    - Knowledge and perspective through data

Mission Interaction Bounded by Communication Time

Round Trip Light Time: ~2.4 S
Comm Latency: Variable
Command to Response time range: 6 - 25+ seconds

Round Trip Light Time:
Variable 134min - 170min



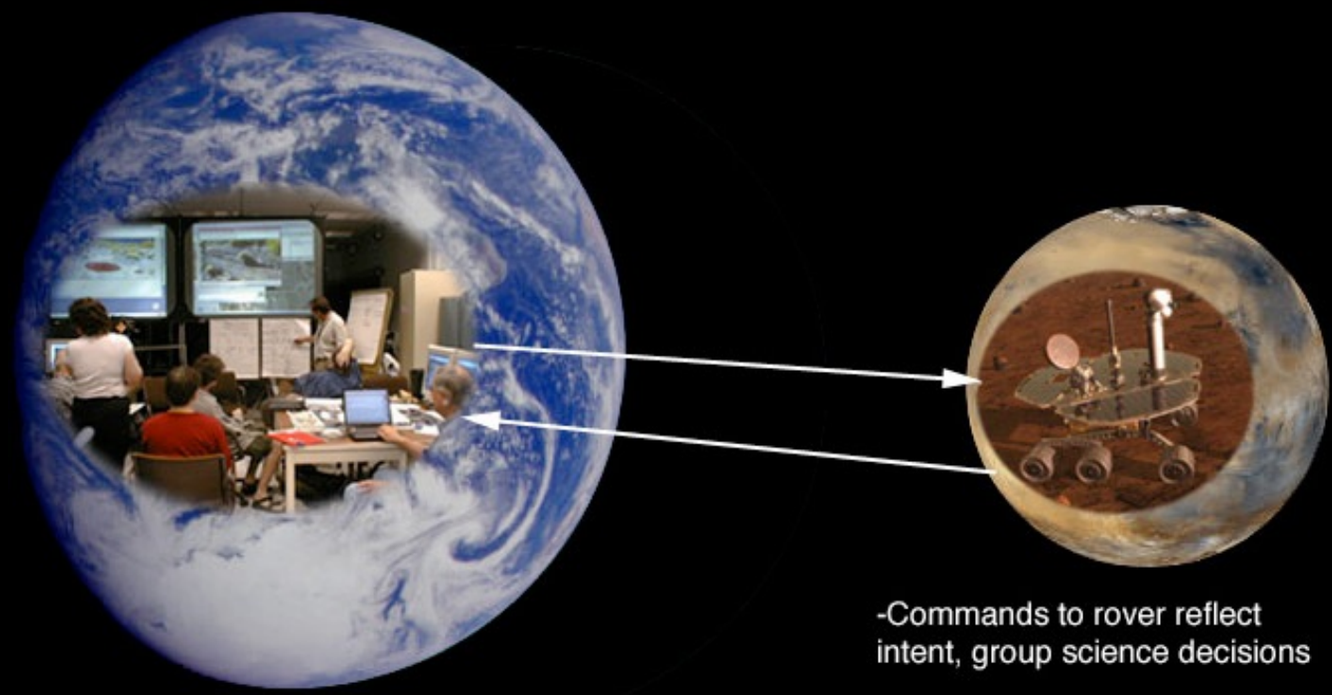
Round Trip Light Time:
Variable ~10 min - 48 min

Mission Control for Crewed Missions

- What is the optimal ground/crew distribution of work?
  - System status and health, housekeeping
  - Planning
  - Trajectory
  - Authority

Mission Control: Earth to Mars (MER)

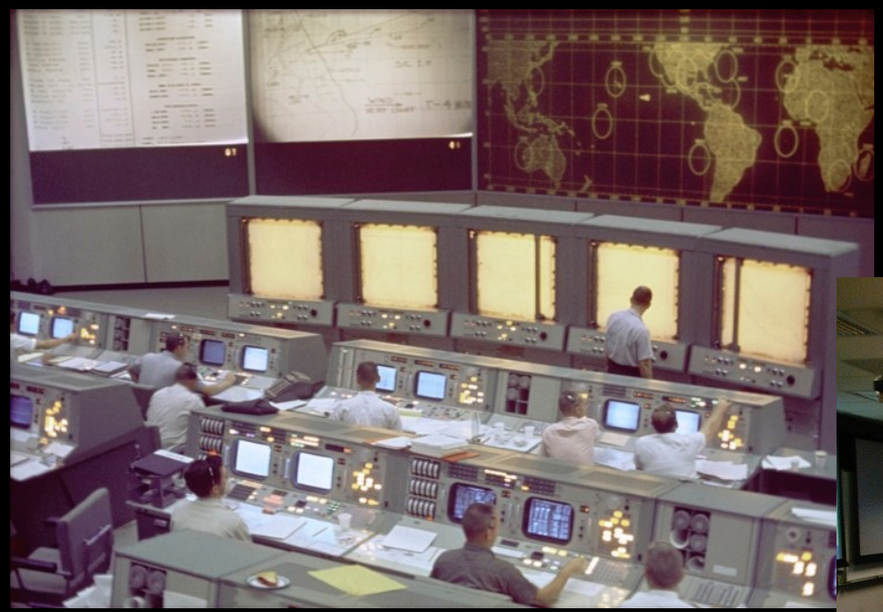
- What is the optimal ground/robot distribution of work?
- All from the ground
- Limited onboard autonomy



-Human Science Team with Computer tools
-Intent, Qualitative Assessment, Judgement,
-Science Priorities, Resource Management

-Commands to rover reflect intent, group science decisions

Control Centers



Disciplines, Call Signs Examples

- NASA
  - Flight Director
  - Systems
  - Trajectory
  - Payloads/POCC
  - INCO
- Star Trek
  - Captain (Kirk, Janeway, Picard, Cisco,…)
  - Engineering (Mr. Scott)
  - Navigation (Chekov)
  - Science Officer (Spock)

Apollo 11 - Nominal

Go for Landing

Apollo 11- Anomaly

1201 Alarm

Apollo 13

Space Shuttle ATO

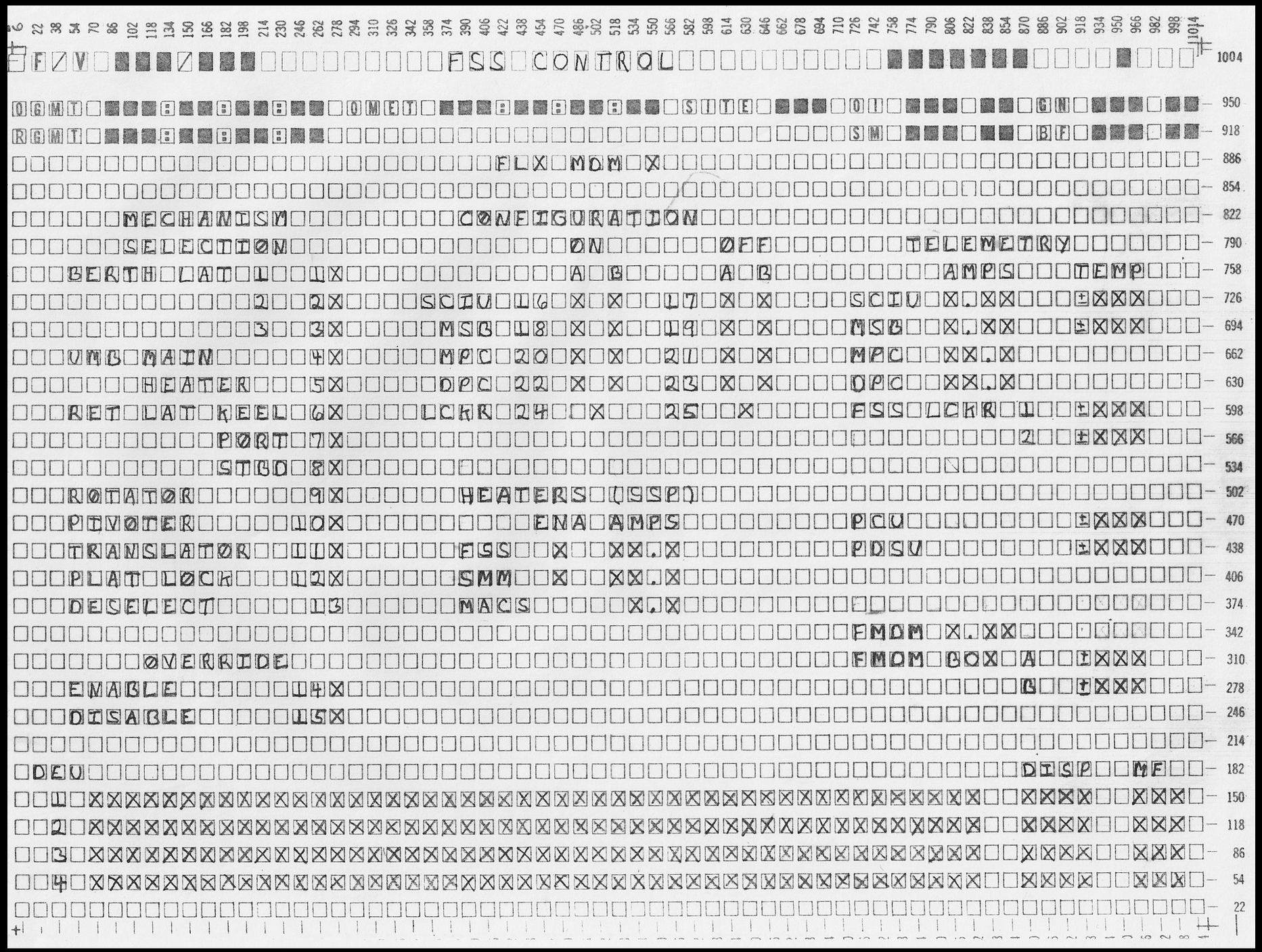
What do the consoles do?

Once upon a time…

In Houston,
Summer Intern, 1981

Lead Ops Director
SRL-1, 1994

MCC Display 1984

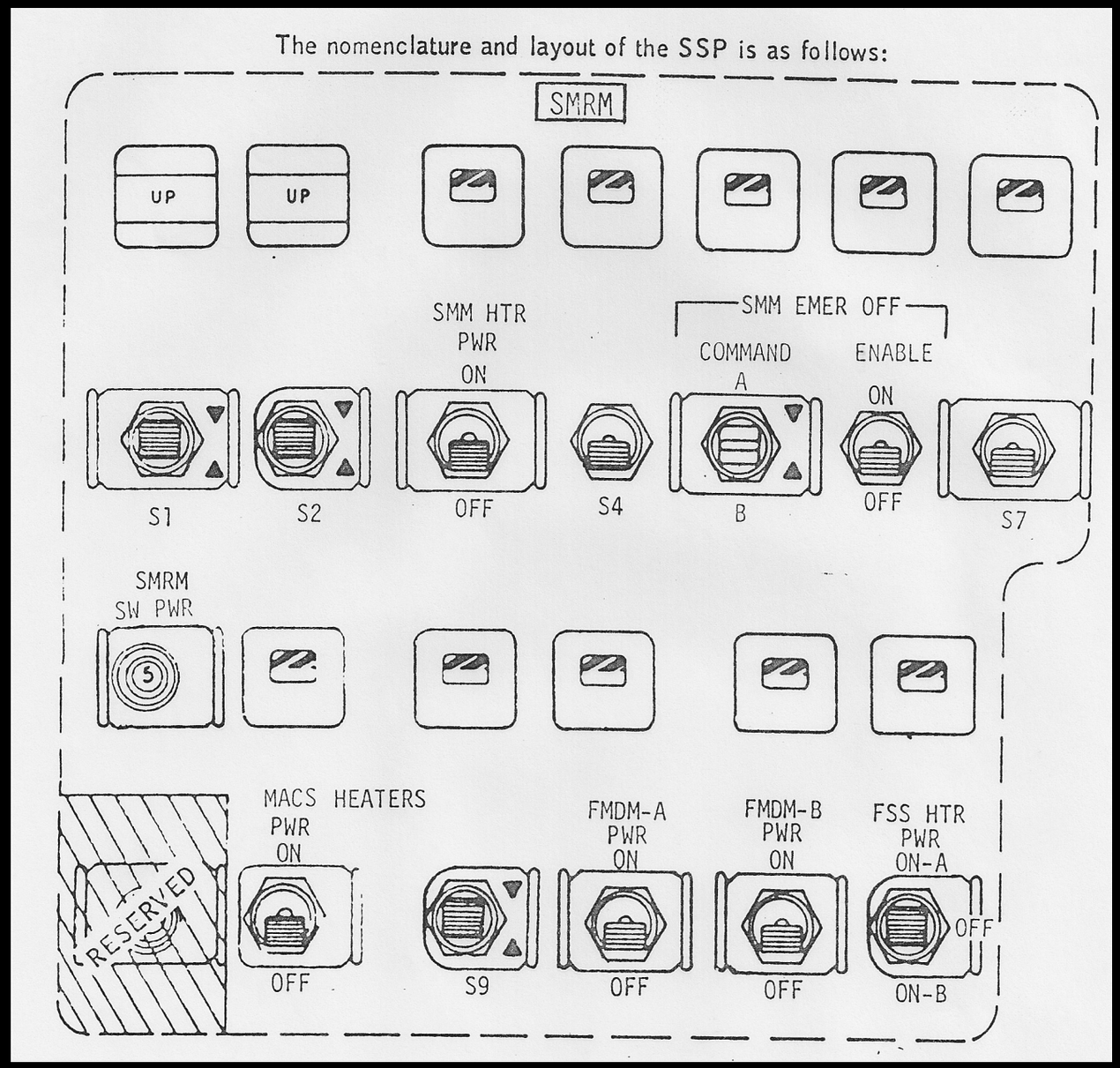


MCC Display 1984

```
 2      7      0      DAY 1      0      1

F/V  13/099                FSS CONTROL                    RR3408A CH044

OGMT 101:18:12:32 OMET   4:04:14:32 SITE TDR OI 188     GN  62
RGMT 101:18:12:32 U/D RATE 1                SM  64     BF  12

     MECHANISM
     SELECTION
 BERTH LAT 1   1
           2   2
           3   3
 UMB MAIN      4
     HEATER    5
 RET LAT KEEL  6
           PORT 7
           STBD 8
 ROTATOR       9
 PIVOTER      10
 TRANSLATOR   11
 PLAT LOCK    12
 DESELECT     13

     OVERRIDE
 ENABLE       14*
 DISABLE      15

DEU
 1
 2 RESUME
 3
 4 RESUME

                CONFIGURATION
                    ON        OFF
                    A B       A B
 SCIU 16  *      17          *
  MSB 18         19  *   *
  MPC 20  *   *  21
  DPC 22         23  *   *
 LCKR 24    *    25

 HEATERS (SSP)
      ENA AMPS
 FSS   *   0.2
 SMM       0.1
 MACS      0.1

                TELEMETRY
                   AMPS    TEMP
 SCIU              0.53       2
 MSB               0.07       0
 MPC               4.7
 DPC               0.2
 FSS LCKR 1                  26
          2                  13

 PCU                          5
 PDSU                        -1

 FMDM 0.85
 FMDM BOX A                  26
          B                 -55↓

                   DISP   MF
                   2011   SM
                   2011   SM
                S  20119  GNCS
                S  20119  GNCS

B3      Y84      HR 1      8      MIN 1      2      SEC 3      b
```

Mental model: Display

Shuttle Control Panel



Timeline

41-C PAYLOAD OPERATIONS SUPPORT TIMELINE

MET	KEY EVENT	CREW ACTION	JSC	POCC
04:00:00	•RMS Grapples SMM	Cinema 360 Ops,(Cue Card) (90 sec of approach to SMM before grapple) Cinema 360 Ops (SMM grapple)		
	•Maneuver SMM to FSS Platform	•Reverify FSS/SMM umbilical config. for berthing and connectors powered down		
00:10	•Berth SMM on FSS, close berthing latches, and mate umbilical connectors	Cinema 360 Ops (SMM berthing)		
		•KU-Band - COMM •Maneuver to TDRS TRK Attitude		
00:20	•Umbilical Interface C/O (Crew)	•Configure FSS components for comm via umbilical SCIU ON •Verify SMM tlm •RMS release SMM •Position SMM/FSS for repair ops: Pivot (inform MCC when at 25 degrees),MPC ON,rotate,pivot	MCC verify SCIU voltages ASAP and verify umbilical connectors mated via FSS umbilical monitoring •Confirm STS is configured for comm with SMM via PI/PDI	•POCC DIRECTOR conducts command activity briefing with HOUSTON PAYLOADS
00:30			•POCC-to-MCC Command Flow Test •HOUSTON PAYLOADS inform POCC DIRECTOR ready for Umbilical Interface C/O (SMM tilted to 25 deg; MPC ON)	•POCC-to-MCC Command Flow Test (NOTE: JOIP proc. 11.2)
00:40			•Command activity briefing with POCC CONTROL	•Command activity briefing with HOUSTON P/L DATA
	•S/C C/O (POCC)		•HOUSTON P/L DATA enables remote POCC command panel	•Receive "GO FOR COMMAND" from HOUSTON P/L DATA: •RF Check via PI Send 18 CU NOOPS commands •Verify SMM status and command capability via PI/PDI Config C&DH for comm via PI/PDI Verify status of all subsystems •Notify MCC when finished
00:50				
04:01:00	•Begin SMM OBC LOAD (POCC) (completed approx. 04:05:00MET) IMU Align @ 04:06.15MET ZLV @ 04 07:00MET		HOUSTON P/L DATA will be notified by POCC CONTROL upon start and end of all bank loads	•Begin OBC LOAD (3 revs comm) Initialize OBC for S/W load CAP responses enabled Dump verif. after each 4K bank Halt and reconfigure OBC

Evolving the Technology

- Why evolve the current model - it works and it has worked well for decades
  - Software built as traditional applications creates packaging of functionality that come with operational constraints
  - Duplication, Granularity, heterogeneous environments, different UI's, "walls," bloat

Open Source Mission Control Visualisation

- Mission Control Technologies (MCT)
  - Desktop JAVA
  - Open Source
    - https://github.com/nasa/mct
    - http://ti.arc.nasa.gov/OpenMCT/
- Web Applications for Resource Prospector (WARP)
  - In development, open source coming soon
  - Check http://ti.arc.nasa.gov/OpenMCT/

Why Open Source

- Enables collaboration
- Share ground system technology
- Build a community
- Create a pathway for outside in innovation

A User Perspective

- Displays (no concept of applications)
- Applications
- Objects and Compositions - most users don’t get this
    - Things you can manipulate and views - more users seem to get this
- Depending on your mental model, these could all be viewed as displays

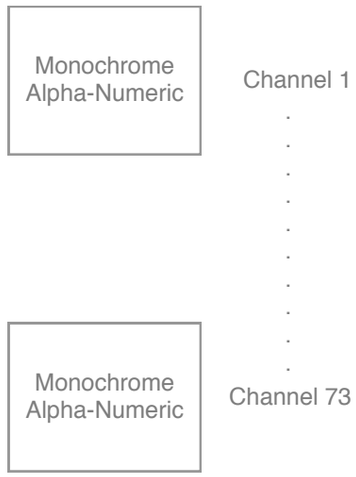
Interacting with our Digital Stuff

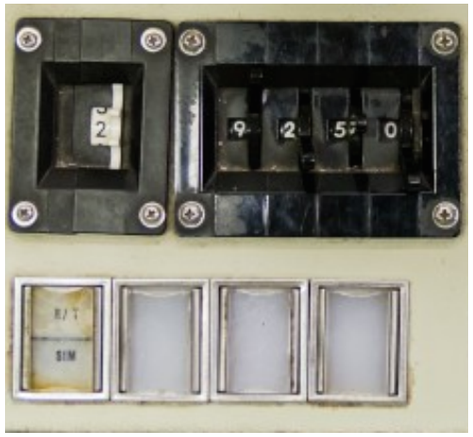
- How do we view and interact with information
  - Applications, apps, widgets, directly with our data
  - Increasing tendency towards sandboxes
  - Where is my stuff
    - It could be in Google Drive, iCloud, Drobbox, Box, or even (heaven forbid) my local file system

Mental Models - Displays, Applications, Objects

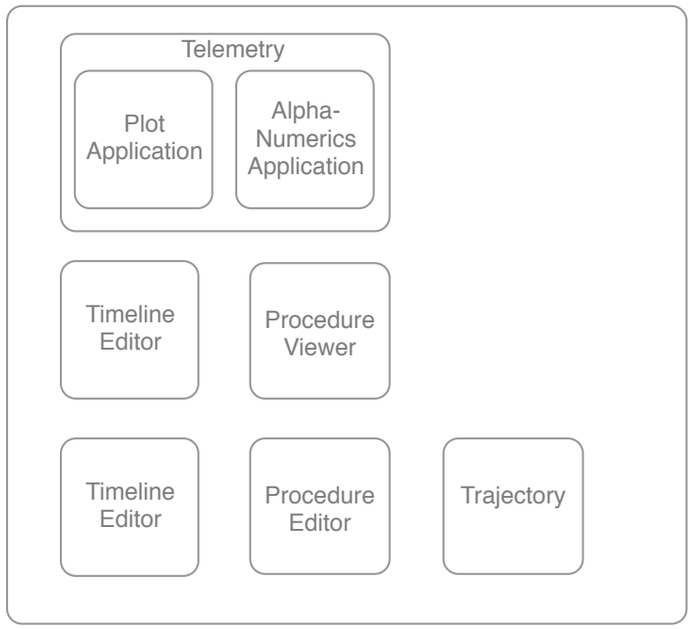
from Gemini to Shuttle

Displays



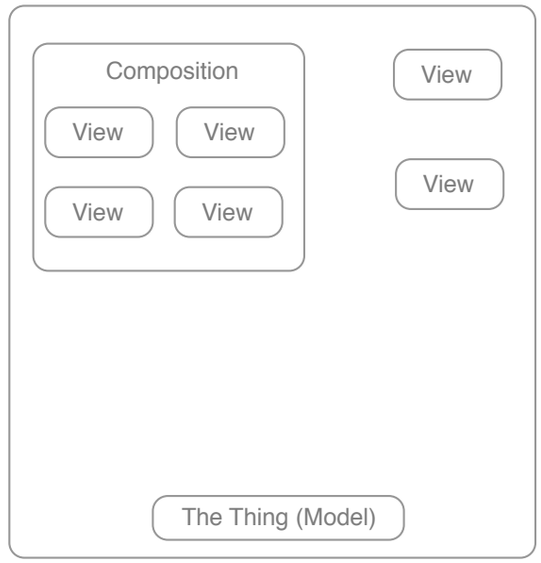


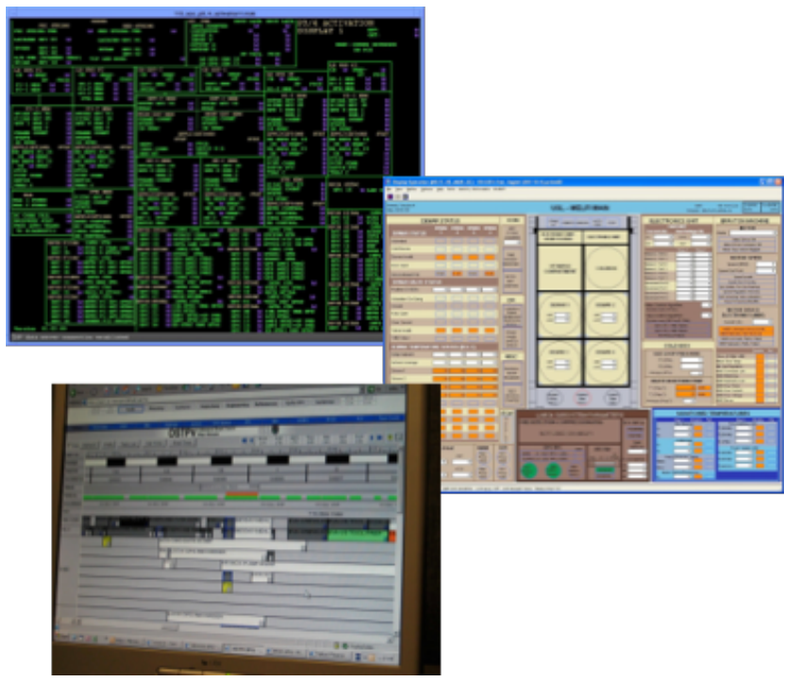
Shuttle to ISS, Robotic Missions

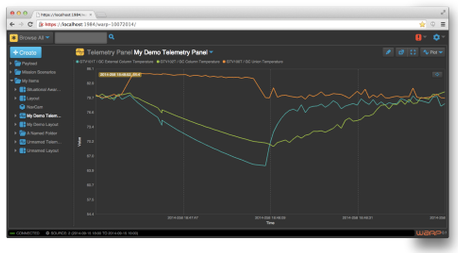


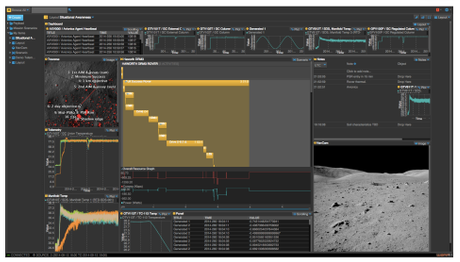
MCT to WARP

Objects, Models, Views

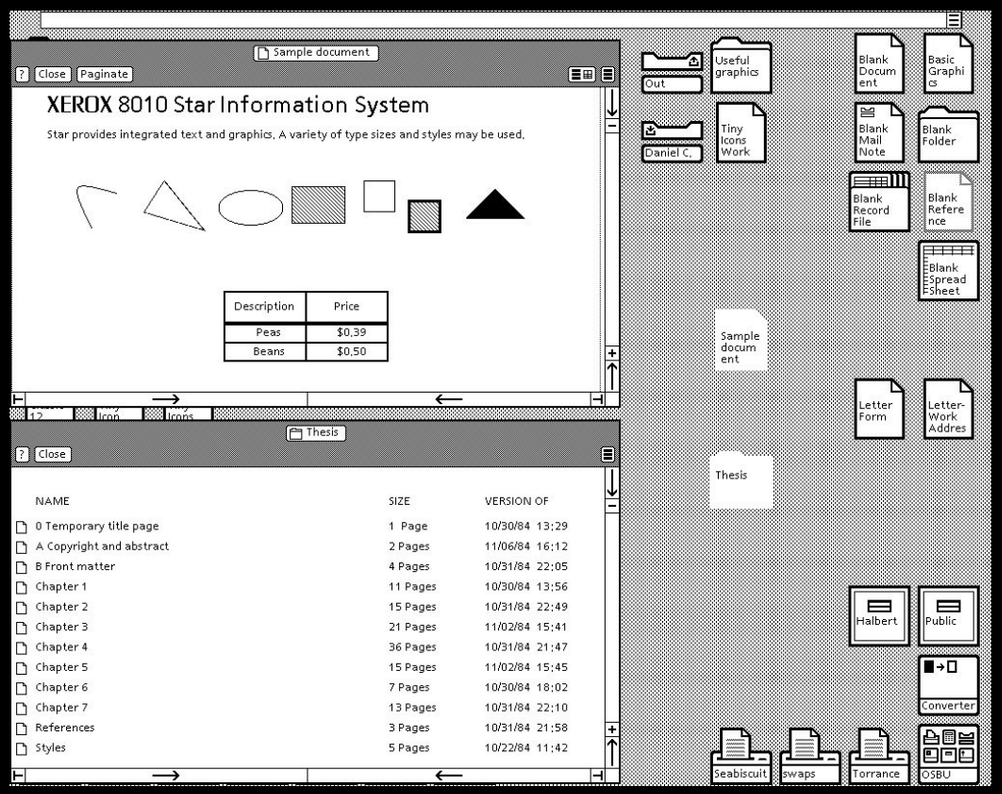








History


Sample document
Close
Paginate
XEROX 8010 Star Information System
Star provides integrated text and graphics, A variety of type sizes and styles may be used.
Description
Price
Peas
$0,39
Beans
$0,50
Useful graphics
Out
Tiny Icons Work
Daniel C.
Blank Document
Basic Graphics
Blank Mail Note
Blank Folder
Blank Record File
Blank Reference
Blank Spread Sheet
Sample document
Letter Form
Letter-Work Addres
Thesis
Close
NAME
SIZE
VERSION OF
0 Temporary title page
1 Page
10/30/84 13:29
A Copyright and abstract
2 Pages
11/06/84 16:12
B Front matter
4 Pages
10/31/84 22:05
Chapter 1
11 Pages
10/30/84 13:56
Chapter 2
15 Pages
10/31/84 22:49
Chapter 3
21 Pages
11/02/84 15:41
Chapter 4
36 Pages
10/31/84 21:47
Chapter 5
15 Pages
11/02/84 15:45
Chapter 6
7 Pages
10/30/84 18:02
Chapter 7
13 Pages
10/31/84 22:10
References
3 Pages
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Styles
5 Pages
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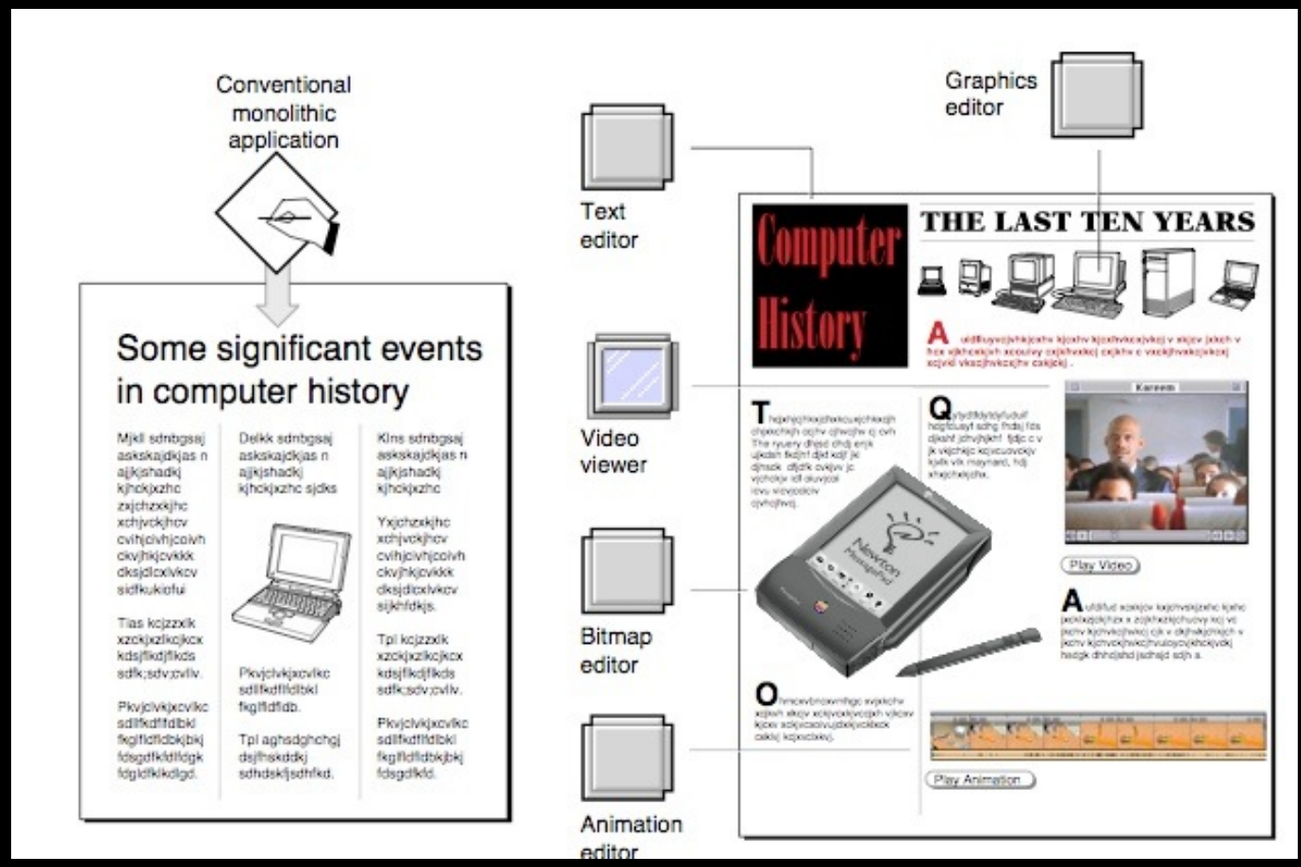
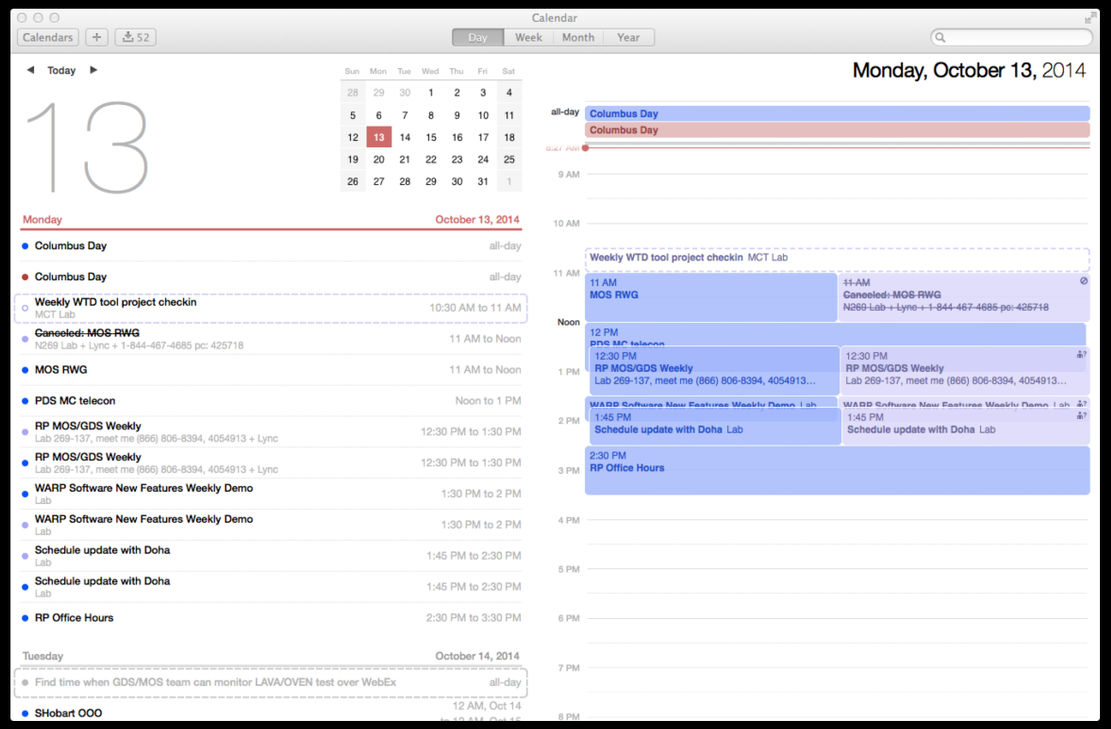
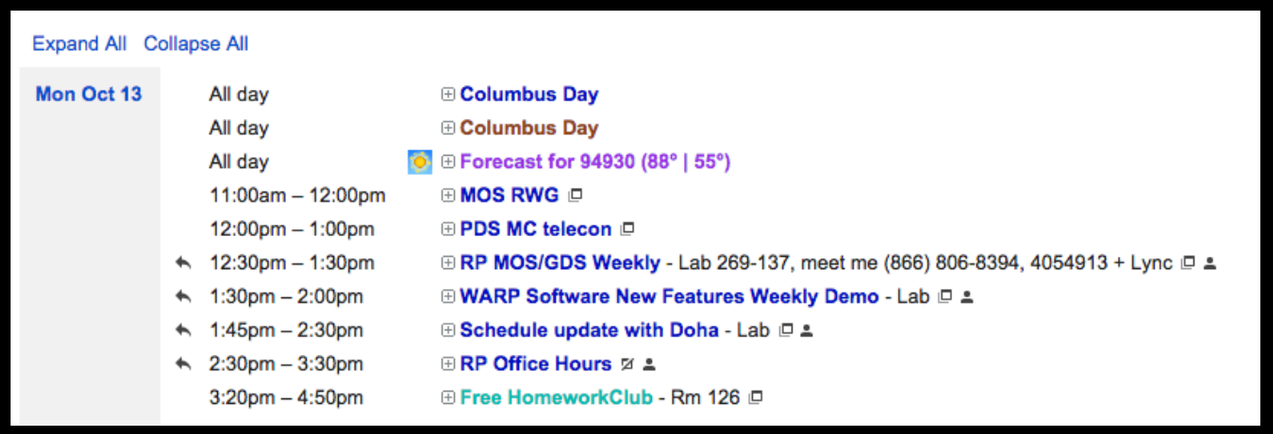
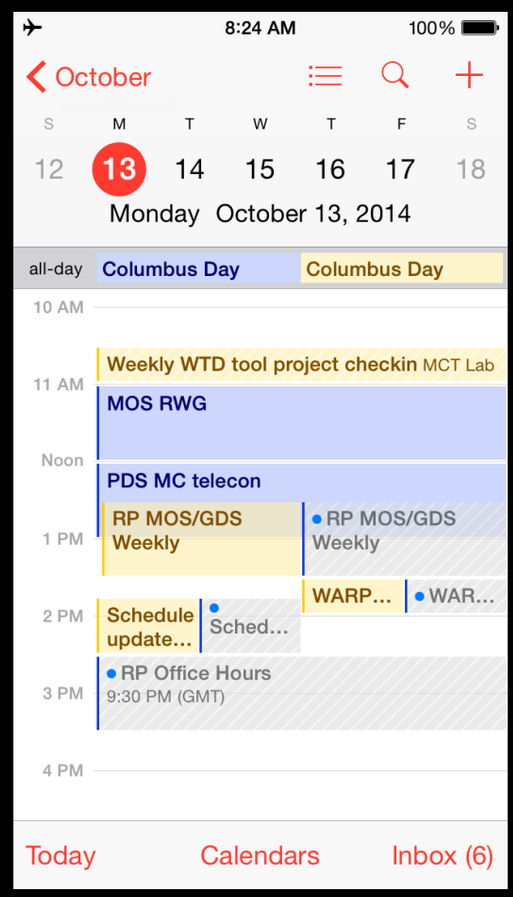
Halbert
Public
Converter
Seabiscuit
swaps
Torrance
OSBU

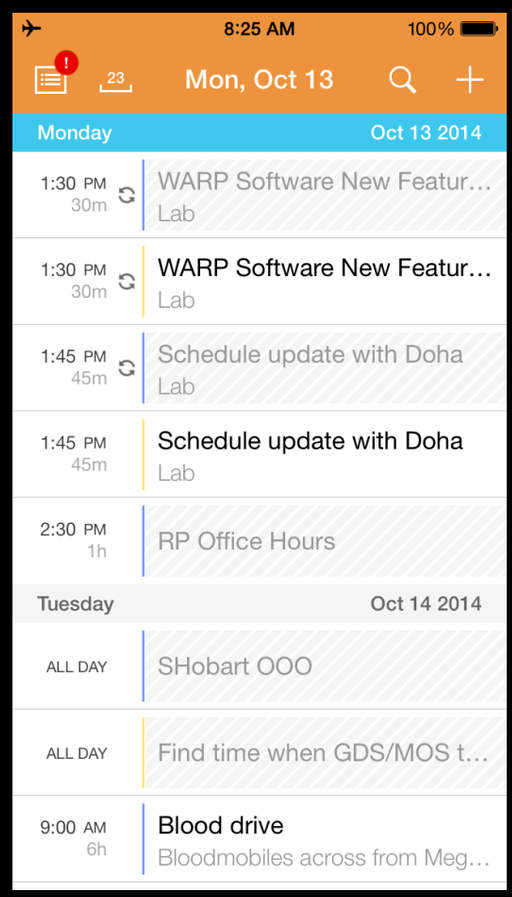

Conventional monolithic application
Some significant events in computer history
Text editor
Graphics editor
Video viewer
Bitmap editor
Animation editor
Computer History
THE LAST TEN YEARS
Play Video
Play Animation

The same thing looks different



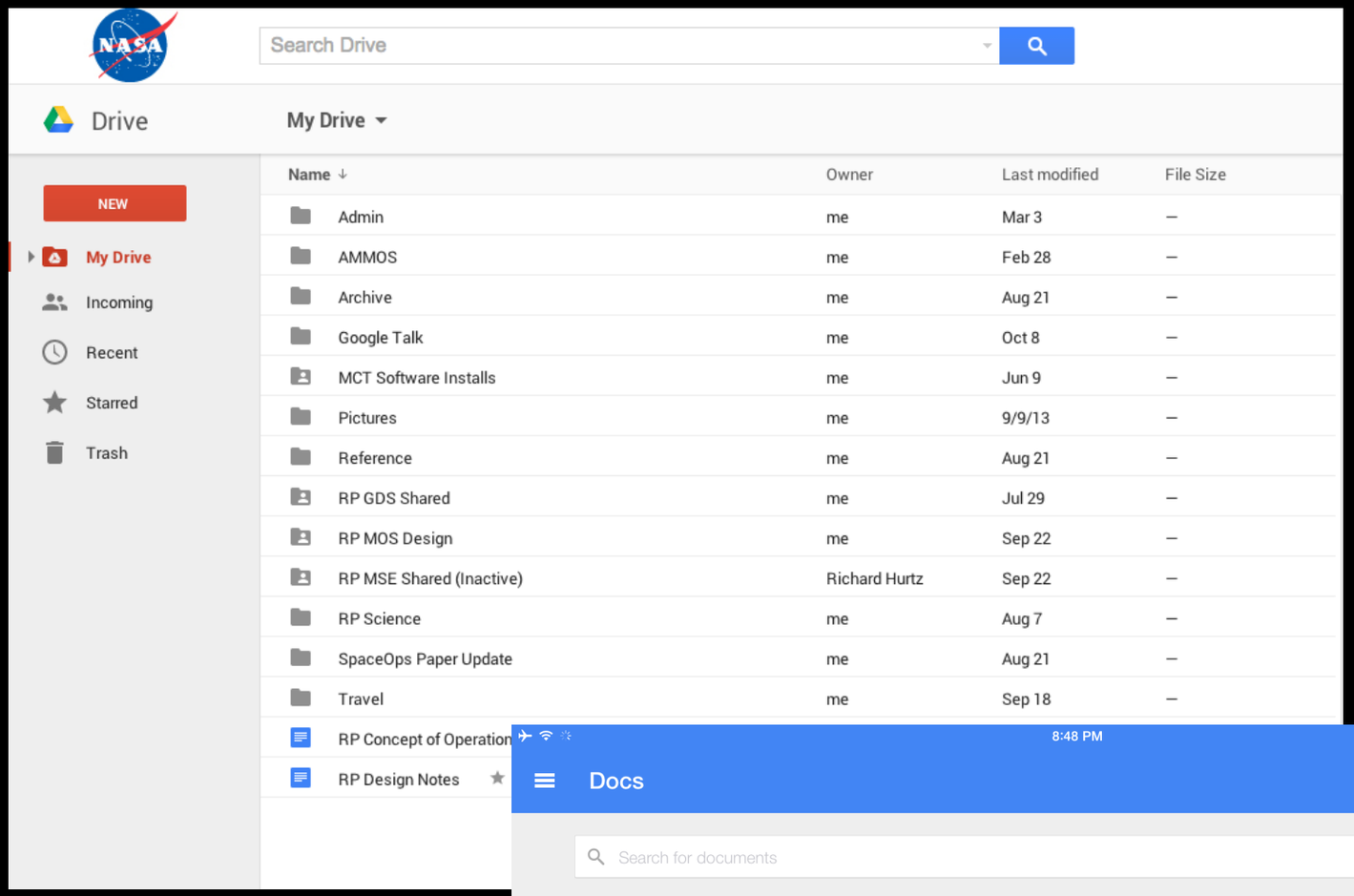


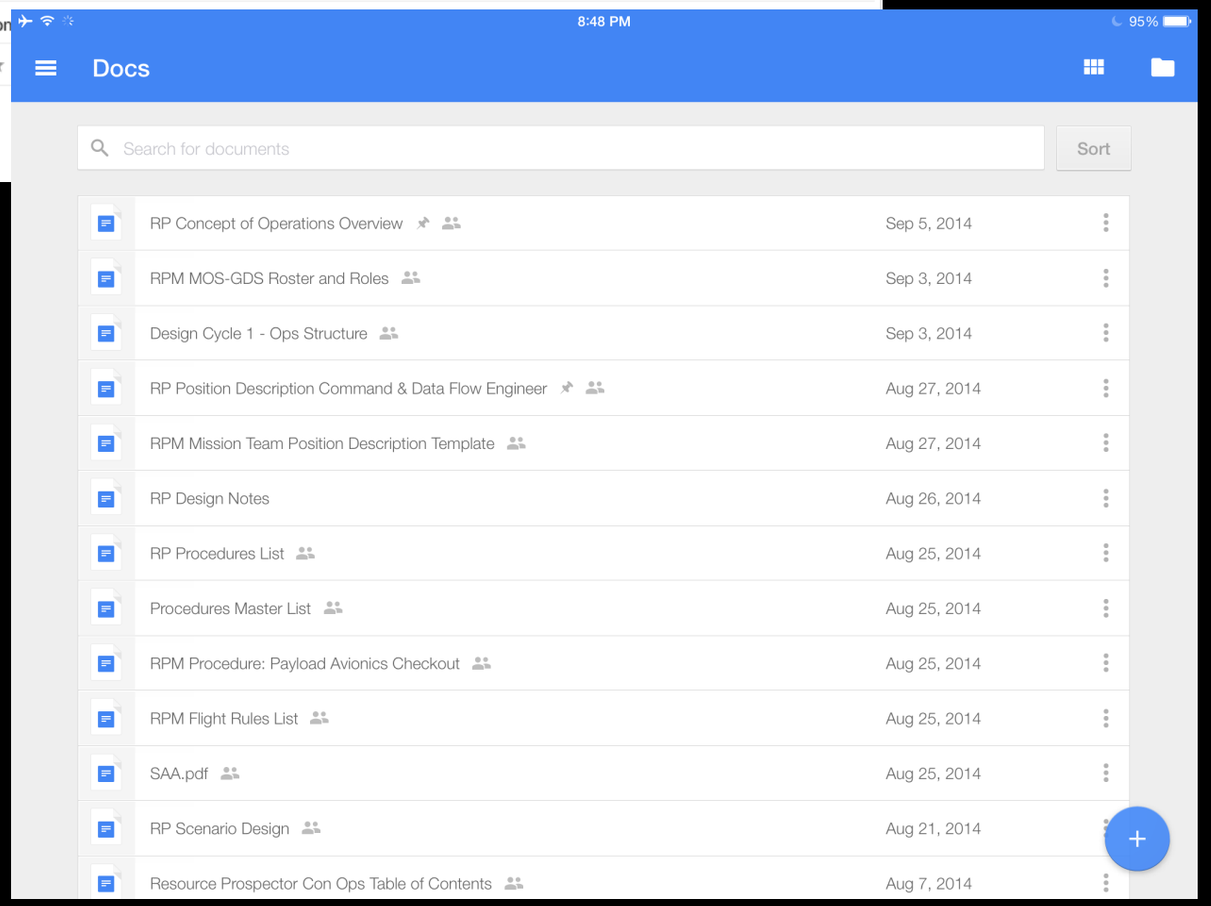




The same thing, diff. views

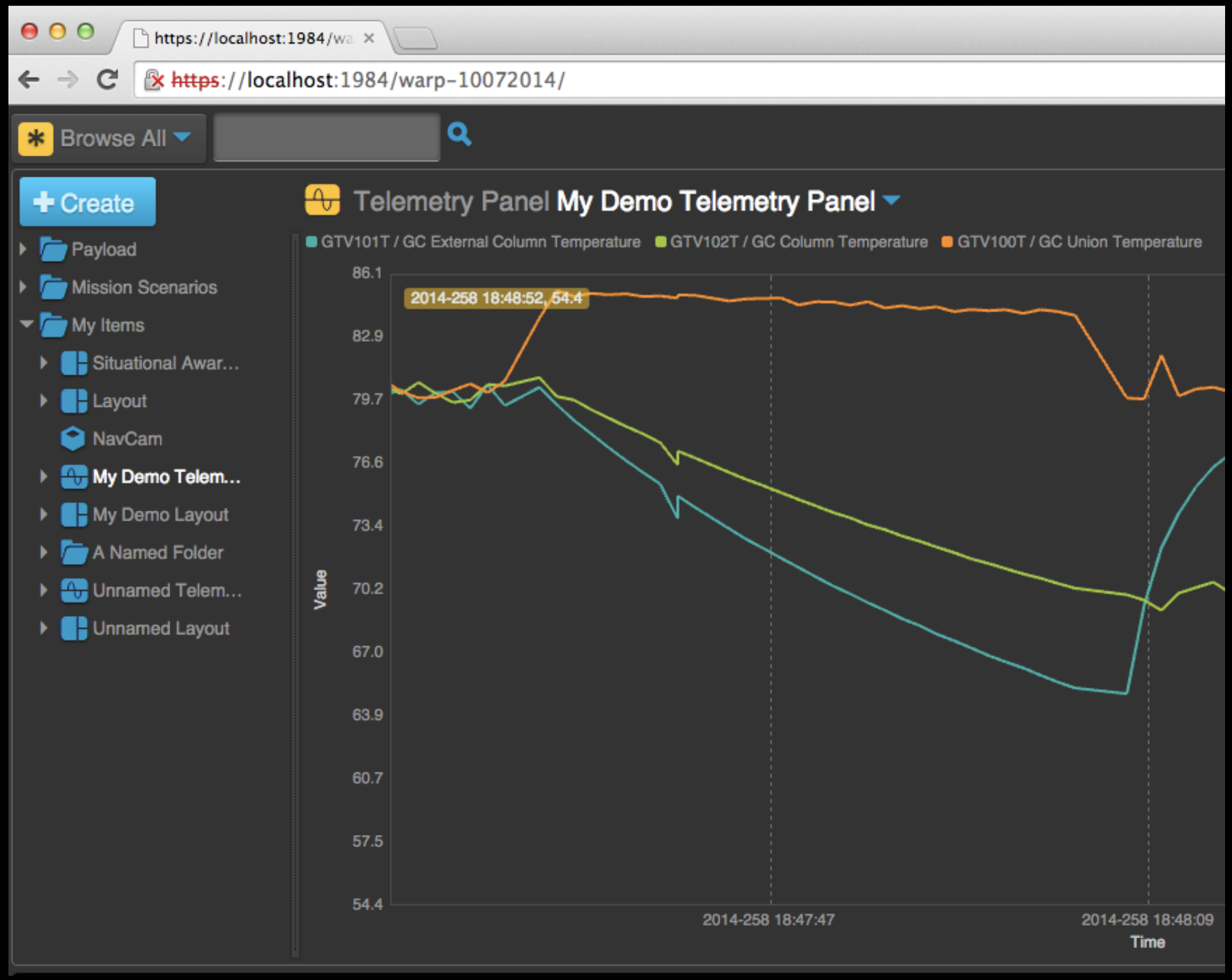
- How do I interact with information?
  - Data centric views, I interact with my stuff
  - Application centric, I interact with applications then use my data?





Our Approach - Integrated User Environment, Objects

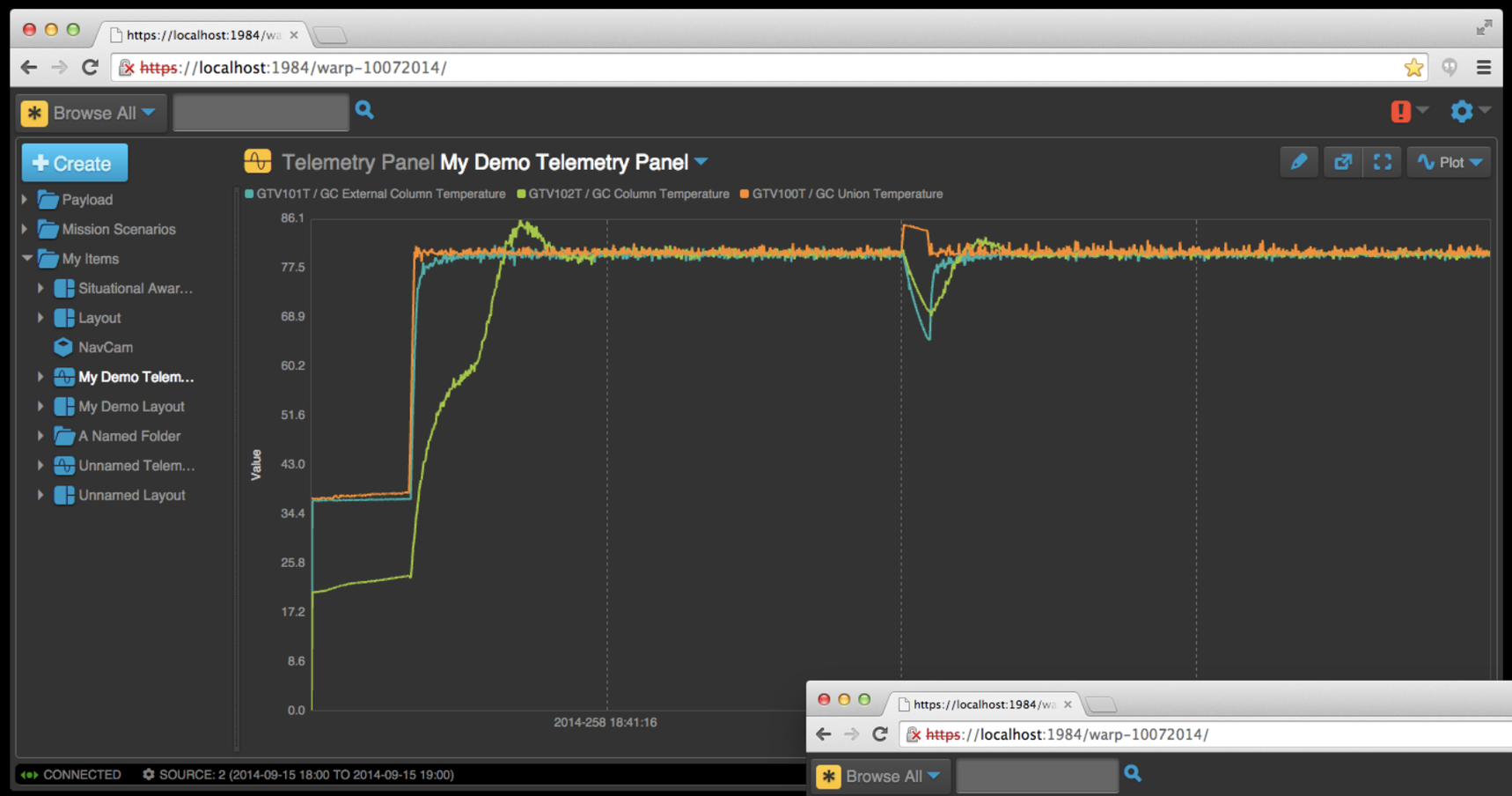
- Interact directly with data
- View that data in different ways
- No concept of separate applications

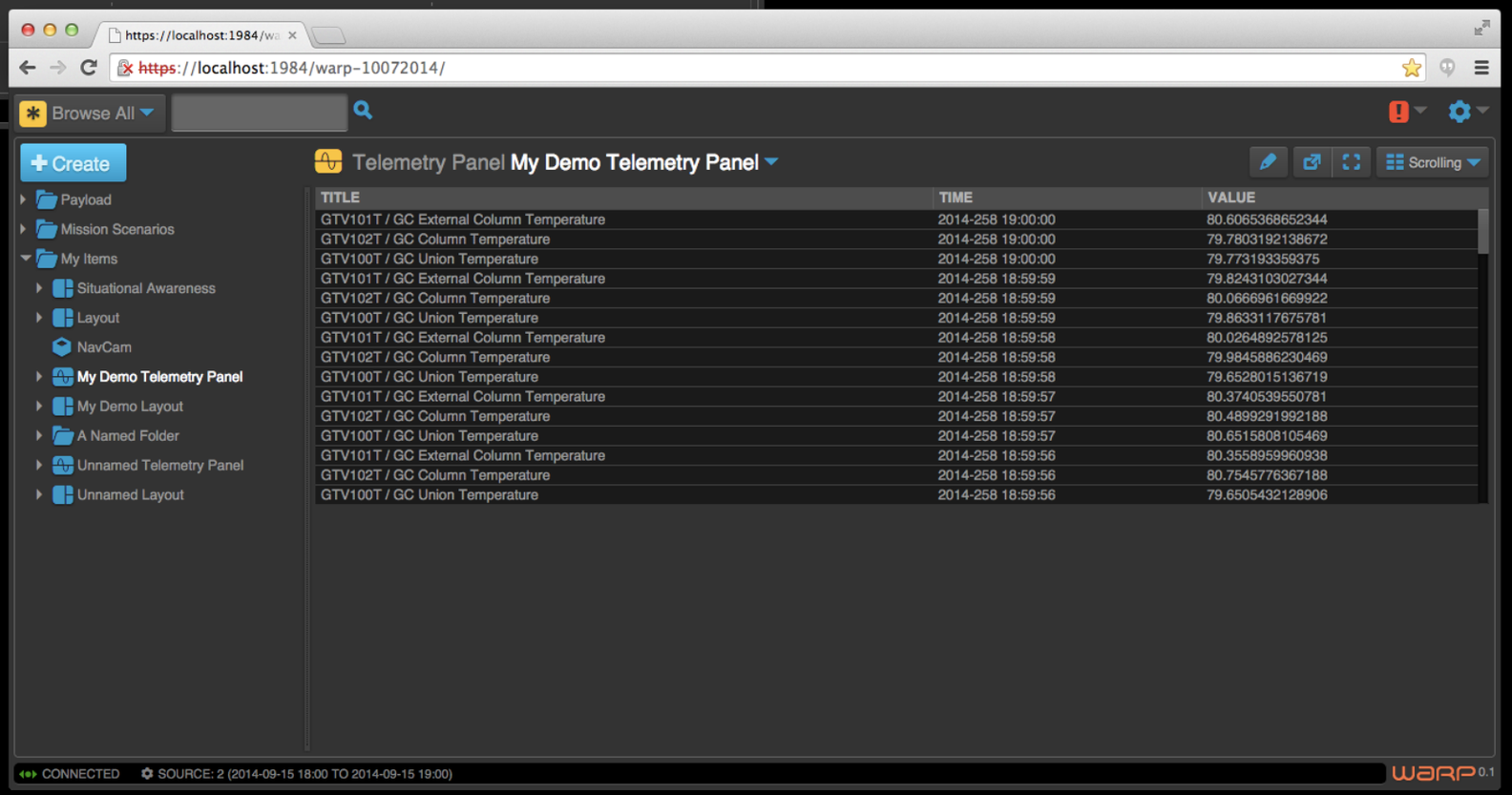


Core Tenets

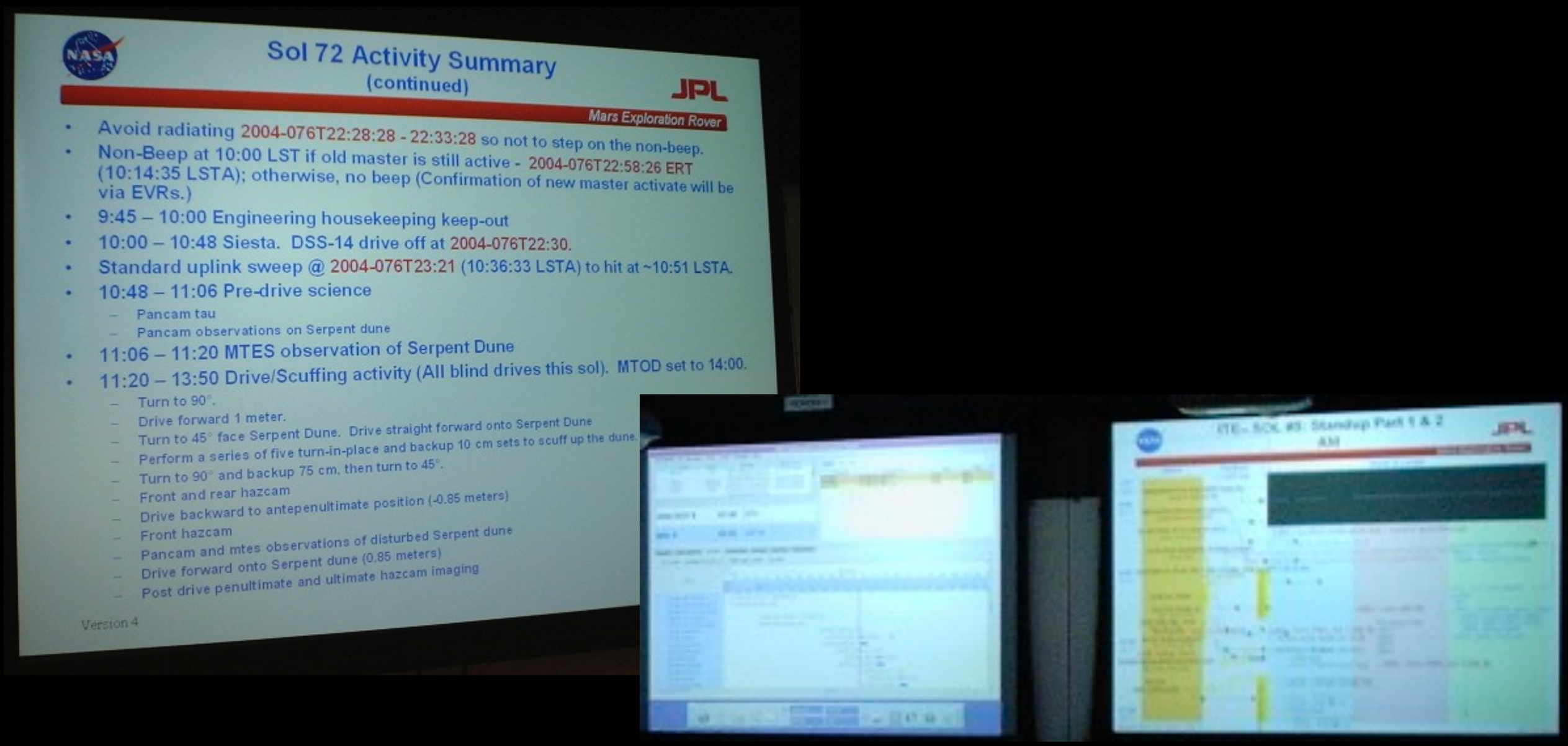
- Objects and Compositions instead of applications
- The same thing in many places
- The same thing, different views

The same thing, different views



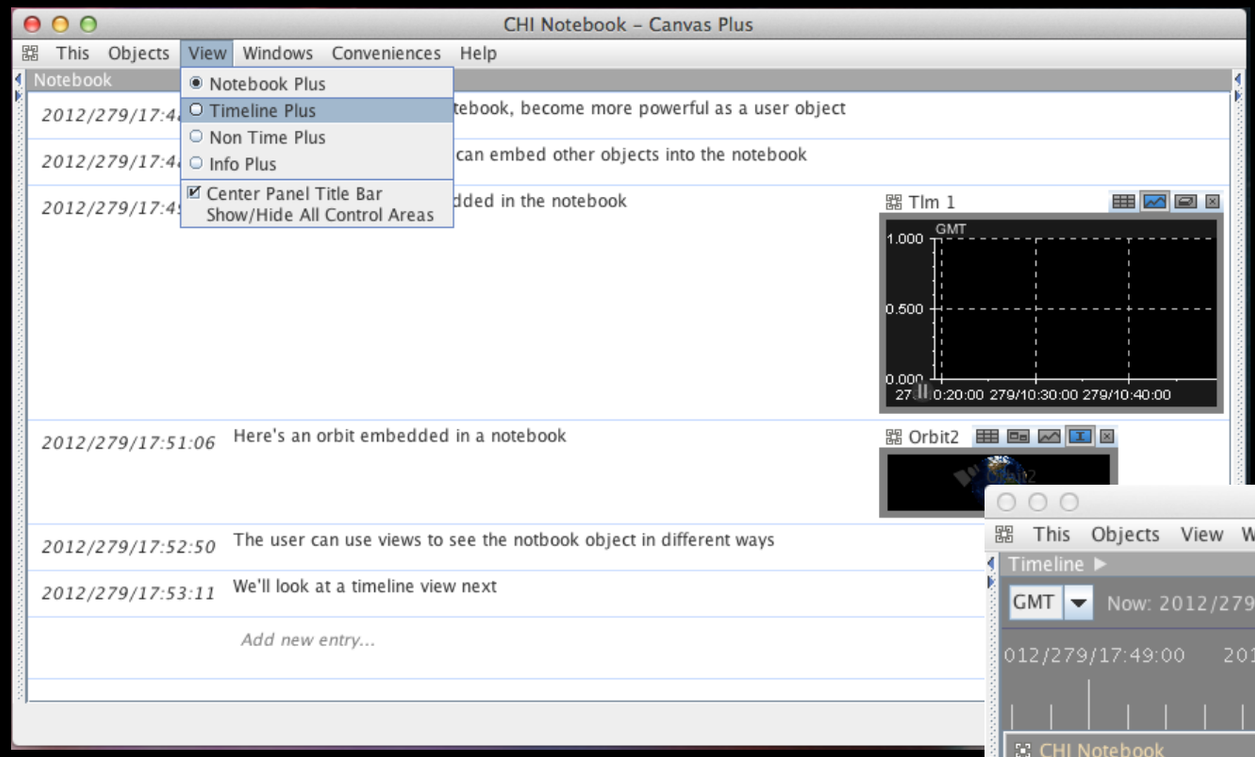


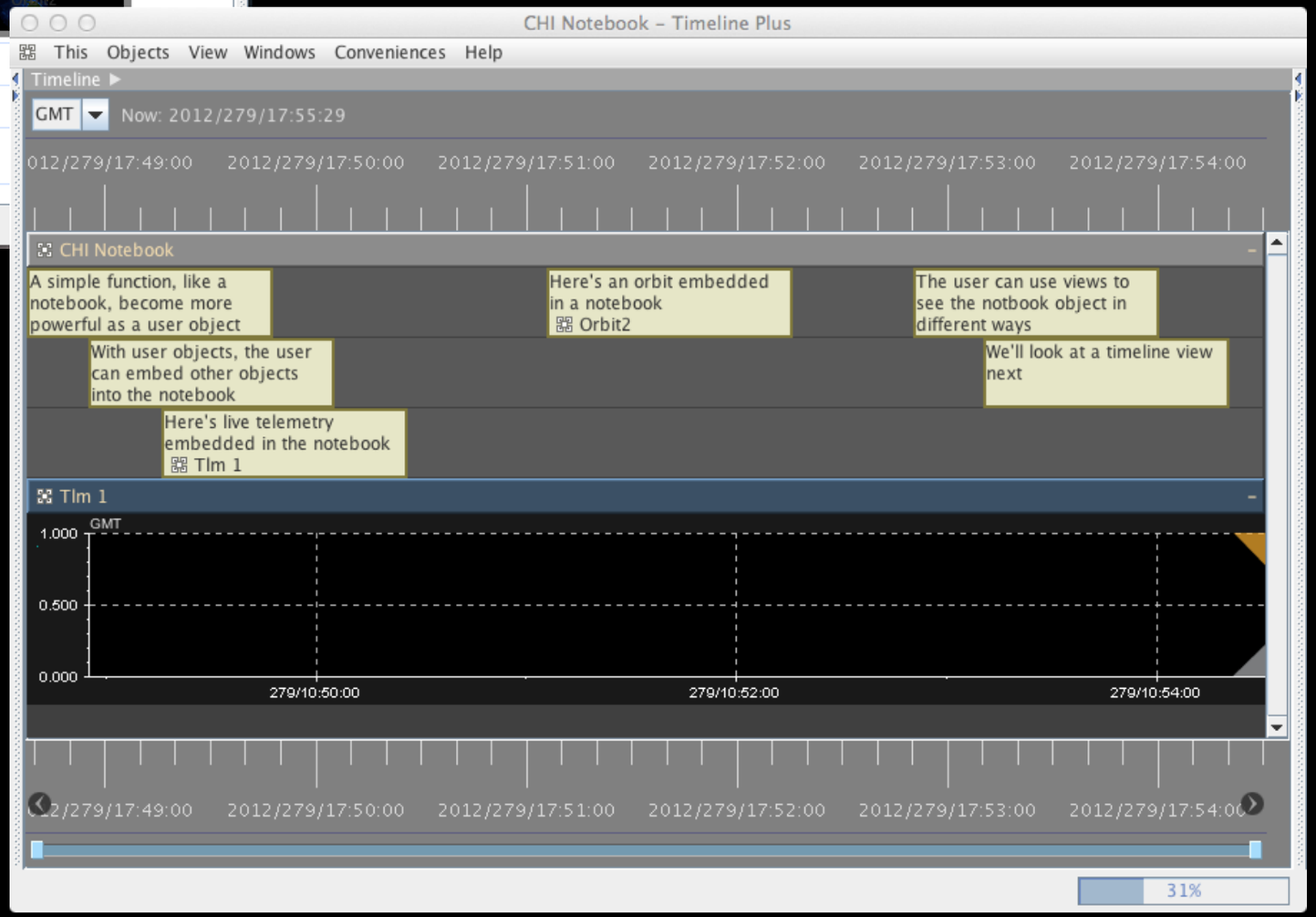
Mission Example



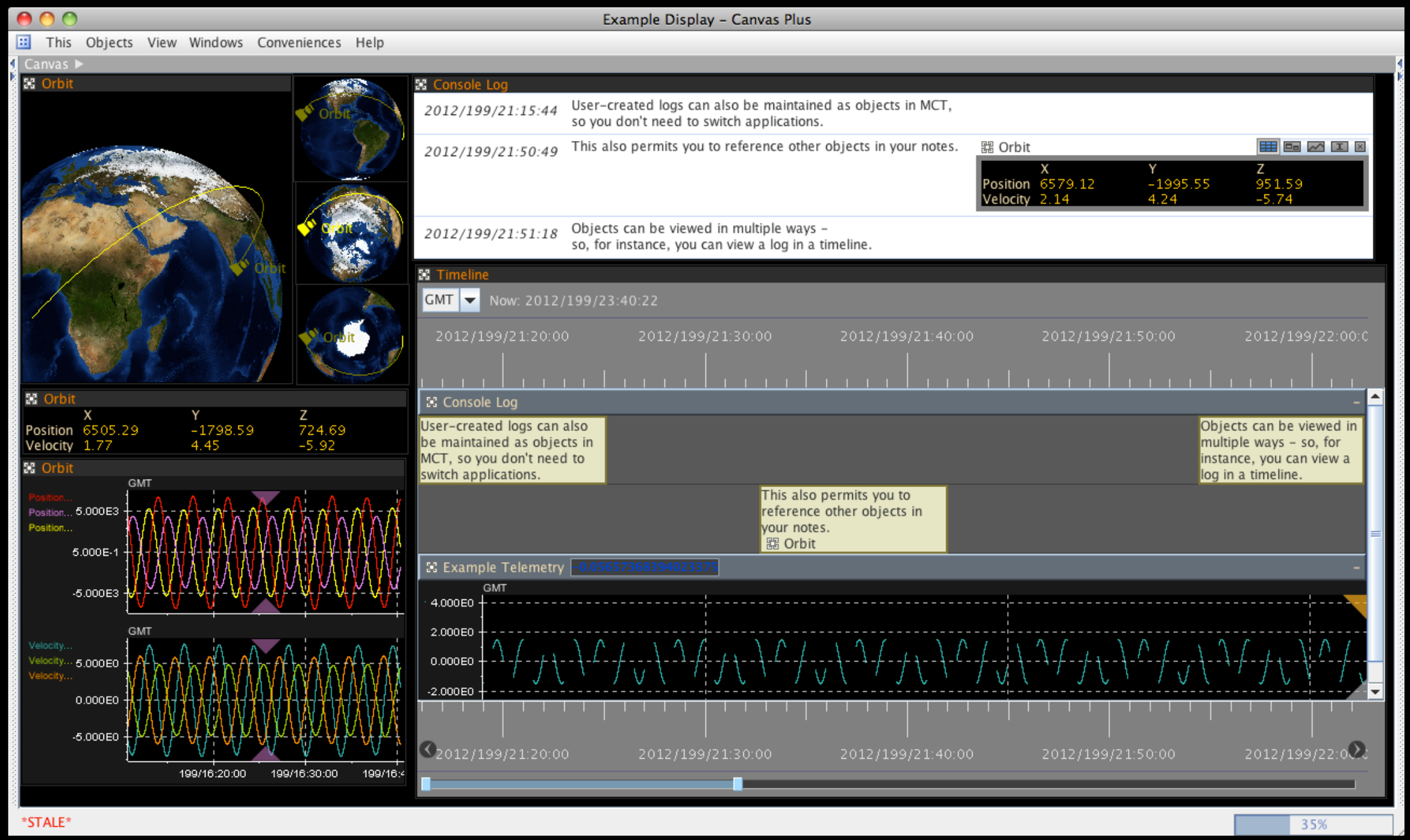
Mars Exploration Rover Timeline Views

Composition/Views

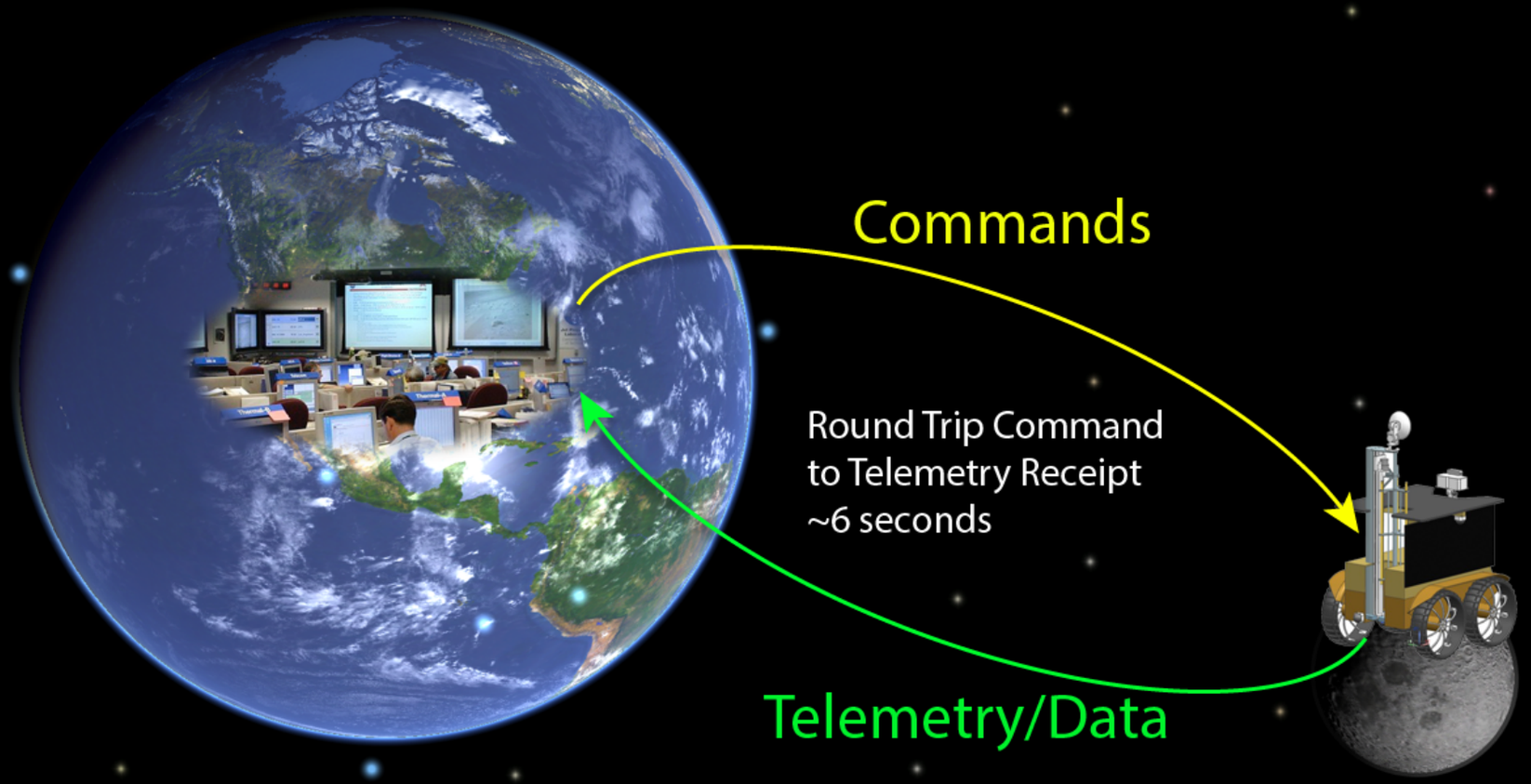




Combining more data types



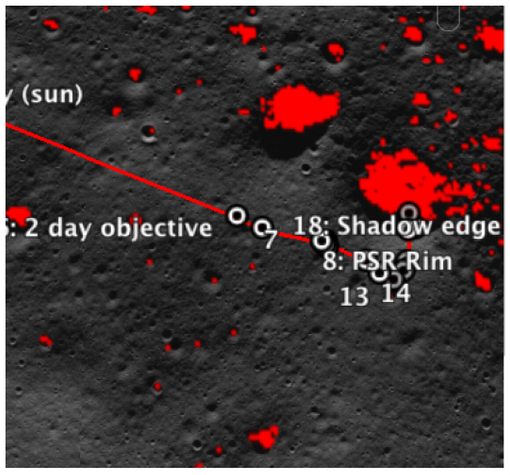
Resource Prospector



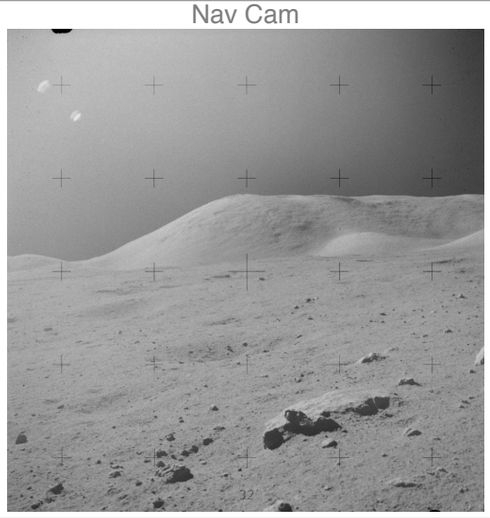
UTC ddd:hh:mm:ss Time to PSR 00:15:00 LOS: ddd:hh:mm:ss FD 2 Shift 1

MET ddd:hh:mm:ss Battery Charge: 99%

Traverse



Nav Cam



Notifications

dd:hh:mm:ss	PSR Pre-Entry
dd:hh:mm:ss	PSR Approach
dd:hh:mm:ss	Drill Secure

Alerts

dd:hh:mm:ss	Rover Thermal	More
dd:hh:mm:ss		More
		More

Timeline

- PSR Pre-Entry Checklist
- Drive to Entry Point 1 — Go/ No-Go
- Rover Thermal Check — Go/ No-Go
- Path Verify
- Nav Cam Verify
- Haz Cam Verify

Predicts

Actuals

Current Procedures

- Regolith Characteristics
- Verify Path
- Drive to Entry Point
- PSR Entry

PSR Entry Procedure

- [ ] Verify Rover Thermal
- [ ] Temp 1

Verify Rover Thermal

Temp 1 xx.x
Temp 1 xx.x
Temp 1 xx.x
Temp 1 xx.x

Add Note

Telemetry

	Volts	Amps
Ch 1 Serial	41.07	41.83
Ch 2 Serial	41.25	41.12
Ch 3 Serial	40.85	41.52
Ch 4 Serial	40.60	41.67

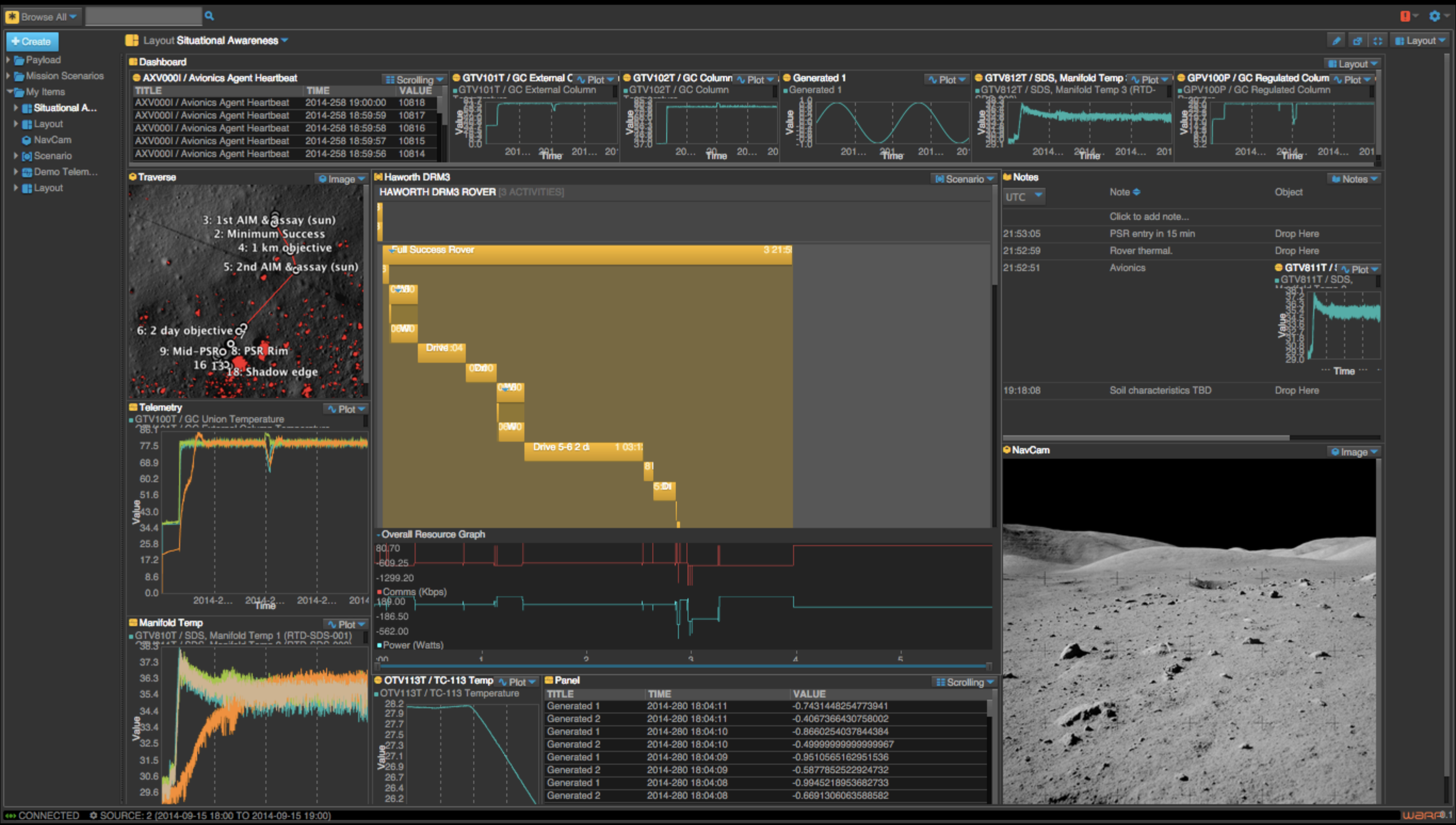
Console Log

Flight Director ▼ | <User Name>

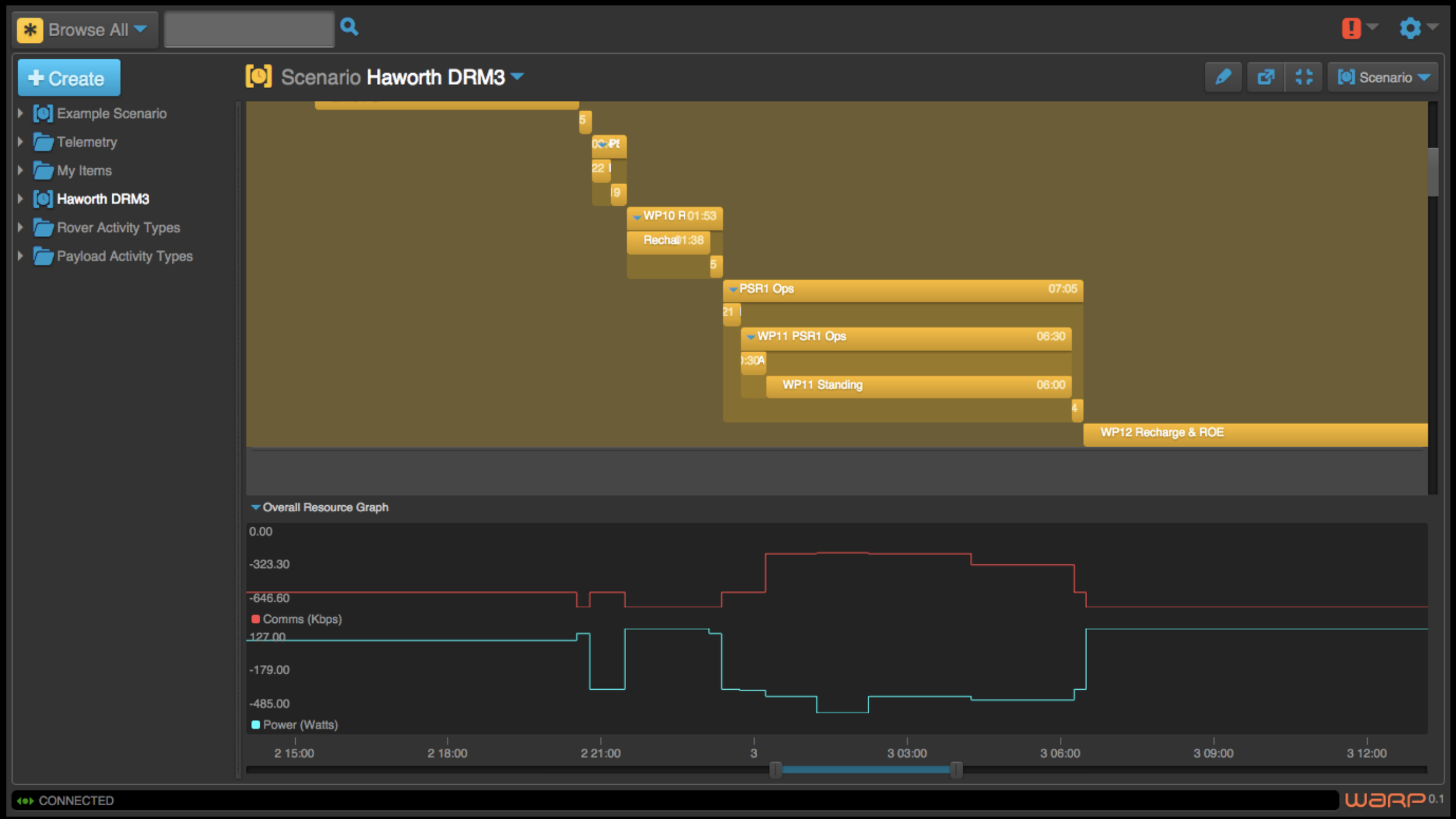
UTC ▼

ddd:hh:mm:ss	Waiting for thermal call from Rover Ops	xx.x deg C
ddd:hh:mm:ss	Science discussing soil properties	
ddd:hh:mm:ss	Rover drive eval nav cam images	

Situational Awareness for Resource Prospector

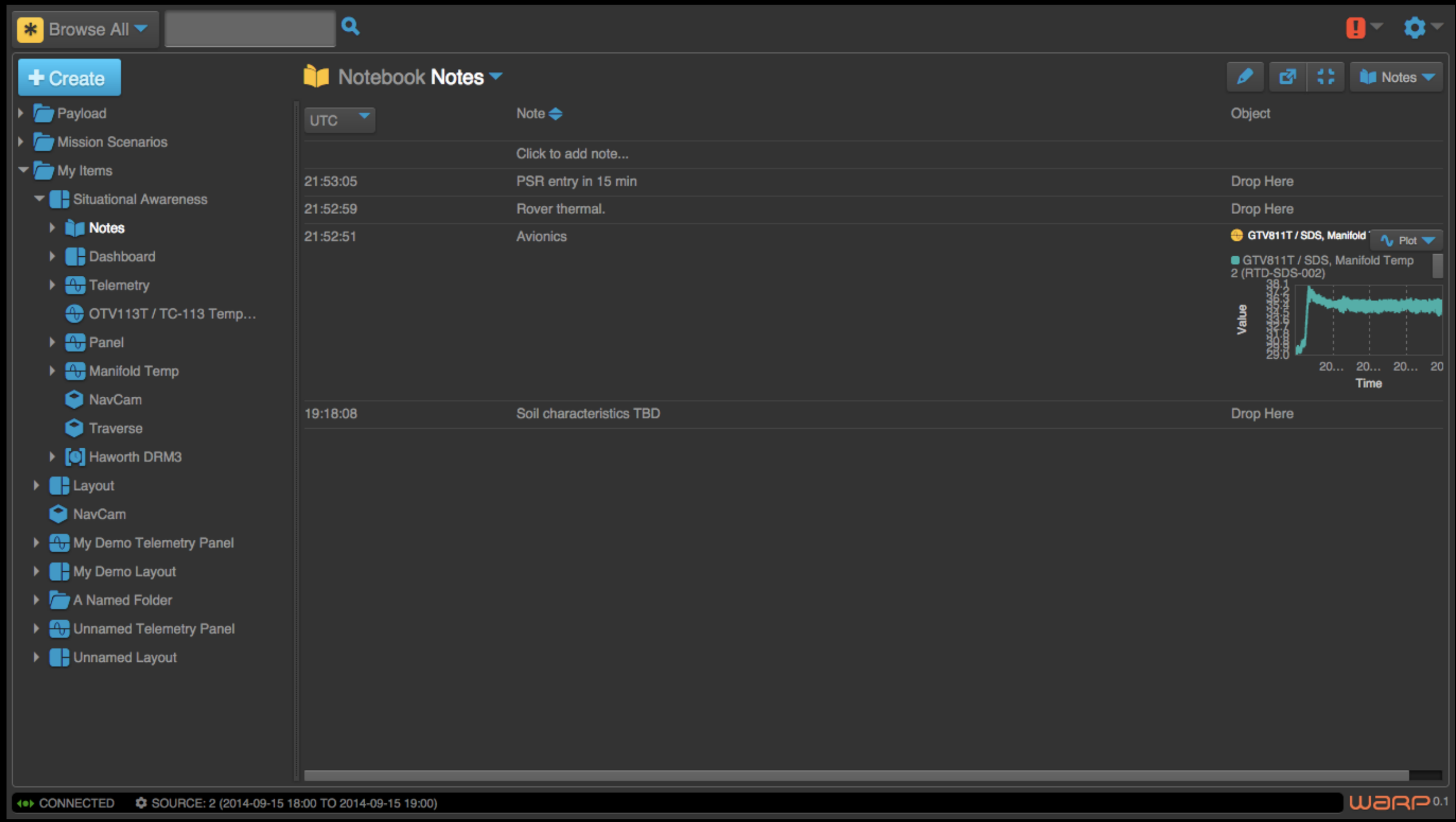


Timelines


Browse All
Create
Scenario Haworth DRM3
Scenario
Example Scenario
Telemetry
My Items
Haworth DRM3
Rover Activity Types
Payload Activity Types
WP10 R 01:53
PSR1 Ops 07:05
WP11 PSR1 Ops 06:30
WP11 Standing 06:00
WP12 Recharge & ROE
Overall Resource Graph
0.00
-323.30
-646.60
Comms (Kbps)
127.00
-179.00
-485.00
Power (Watts)
2 15:00
2 18:00
2 21:00
3
3 03:00
3 06:00
3 09:00
3 12:00
CONNECTED
WARP 0.1

Telemetry - Plots

Notebook with embedded objects



Open Source Mission Control Applications

- We started with Java on the desktop
- Open Mission Control Technologies (MCT)
- On Github
  - https://github.com/nasa/mct

WARP Open Source

- Coming Soon, check
- http://ti.arc.nasa.gov/OpenMCT/
- https://github.com/nasa/mct